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# Image Enhancement of Underwater Images using Deep Learning Techniques

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**ABSTRACT –**

The quality of underwater images is very important for research purpose and ocean exploration. The market for high-quality underwater images is expanding exponentially. Despite this, there are a number of issues including blurriness, dim lighting, poor contrast and color fidelity. Light attenuation, absorption and scattering lower the quality. As a result, it is essential to enhance underwater images, and different image processing techniques are used for enhancement .The deep learning methodology used in this study improves image quality and produce the best outcomes when compared to conventional image enhancing techniques. The architecture used is GAN with the combination of Image processing algorithms as a preprocessing step for implementing deep learning models .The algorithms include Histogram Equalization and Dark Channel Prior. These methods normalizes the contrast of images and removes the hazing or dark parts of the images. The dataset used in this study is EUVP (Paired) which contains about 2186 real-world underwater images. Three parameters, UICM, MSE and PSNR are used to assess quality of enhanced images. The optimum technique for improving the images is determined by comparing the performance of the models after the dataset has been trained through them.

***Keywords*:** Image enhancement, GAN, Image processing, Deep Learning Histogram Equalization, DCP.

## 1. INTRODUCTION

Earth is an aquatic world, with around 70% of its surface covered in water. Lakes, rivers, and seas all contain numerous intangible and valuable resources that are not apparent to underwater cameras. The images that are taken underwater have a blurry appearance and low colour, contrast, and sharpness. Images of the underwater world appear hazy because of suspended particles like sand and minerals found in rivers, lakes, and seas. Image enhancement was implemented to solve these issues.

Image enhancement is the technique of utilizing software to digitally edit a stored image. Filters, image editors, and other tools for changing various aspects of an entire image or particular sections of an image are just a few examples of the many different kinds of software used for image enhancement. They are also crucial for the vision function of ROVs and autonomous underwater vehicles (AUVs). In conventional air-based images possessions cause by the medium's physical properties are not visible. Underwater photos are distinguished by their limited visibility, which results in photographs with low contrast and haze. This is because light is gradually attenuated as it flows through the water. The processes of light absorption and scattering in water have an impact on the overall performance of underwater imaging systems. Computer vision research on low-light picture augmentation has developed to ensure that the gathered low-light images can be used efficiently, a hub for research in the area. Using several technological techniques, such as denoising, altering the picture backdrop and edges, and enhancing overall and partial image contrast. Artificial lighting has the potential to increase visibility, but it also has the drawbacks of dispersion and absorption. Moreover, it has a propensity to illuminate the environment unevenly, producing a dazzling point in the image's centre and a poorly illuminated area around it. Water absorbs light selectively i.e., the absorption rate of red light is higher, while the transmission rate of blue and green light is higher. Raw underwater photos are therefore more blue or green than in-flight images. Finally, as we journey farther into space, the intensity of the light drops in line with the wavelengths of the various hues.

FUnIE-GAN does not take into account channel efficiency, making it ineffective for addressing the real-time, large-scale underwater improvement problem. The accumulation of water particles also casts a shadow on the light emission Because of this, the particles may alter the direction and angle of direct light travel in water. Retinex and wavelet transform technologies are two common methods of improving images. The physical degradation model, which is the foundation of image restoration technology, estimates the interference elements that affect image clarity using prior knowledge and expectations. By reversing the degradation process, the effect of interfering components is decreased while image clarity is improved. available (IFM-free). Color casts, artefacts, and increased noise are easily created even though typical underwater image enhancing approaches ignore the optical features of underwater imaging. Conventional restoration techniques rely on a specific prior, which introduces artificial light sources, complicates and limits parameter estimate, makes it difficult to solve colour fidelity issues, and adds complexity to parameter estimation. When conventional image-enhancing methods fail to correct some obviously warped images or yield mediocre results due to the level of technology, deep learning technology has taken their place.

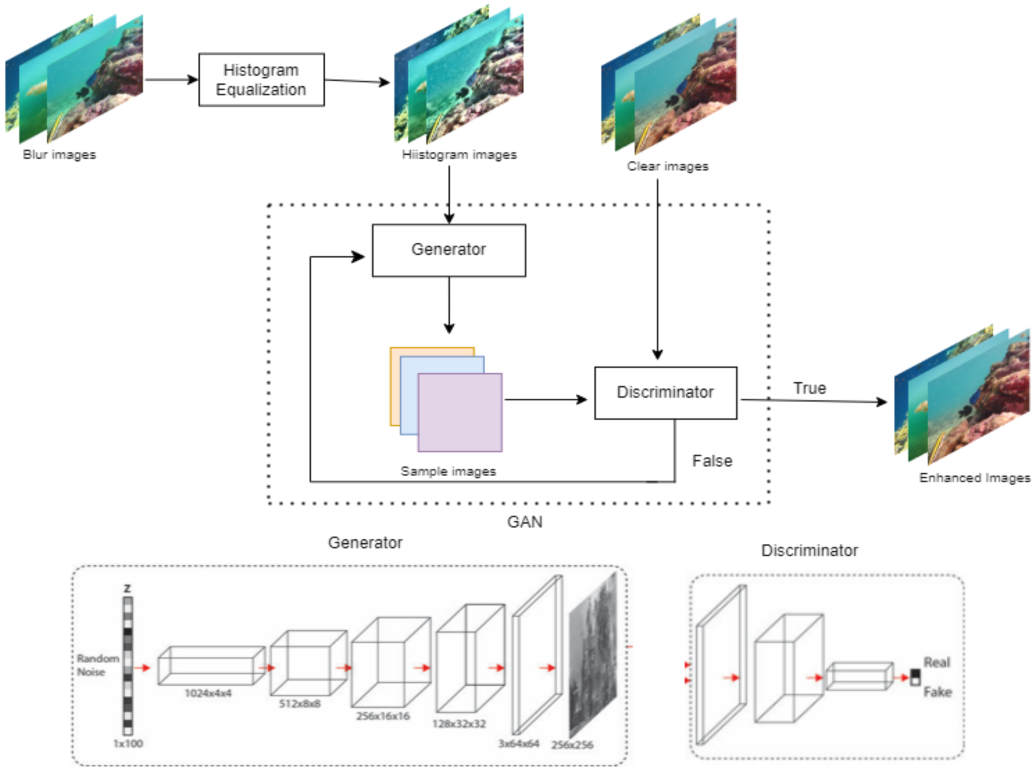
This study explores the drawbacks of current image enhancing techniques and suggests a deep learning model in combination with image processing technique.

## 2. LITERATURE SURVEY

[1] Xu, B., Zhou, D., & Li, W explains an image enhancement method based on GAN architecture and improves efficiency of enhancing images with more blurriness, dim and unclear parts .The generator part generates images by passing through the U-Net and ADFF modules. The discriminator differentiates the real and generated fake images and results the enhanced image. The DIARETDB0 and SID are the datasets used in this study and the comparison of GAN based method is done with the multi-scale Retinex based Histogram Equitisation. This method is ahead of all other algorithms and reaches the best results, and can restore details and natural colors. The metrics are UIQM, UIConM, UCIQE, Entropy . By using this method , the brightness ,detailed information ,quality and color of the image improves efficiently. This method doesn't restore the details of overexposed areas well hence the future work aims to focus on solving details of enhancement to restore exposed areas. [2] Zhou, X., Zhang, J., & Zhou, F worked on the problem of gray-scale loss in the existing pseudo color methods in high gray-scale image enhancement. Author proposed a Dynamic heterogeneous feature fusion neural network to solve the problem of grey-scale loss. They combined high gray-scale enhancement algorithm and convolution neural network and used to extract the features of the multi-scale image. Author improved the brightness of the image, the problem of color distortion and brightness blocking of the enhanced image. Author used Structural Similarity metric also called as SSIM to compare the results and the method proposed in this paper has achieved the best results with SSIM 85%.[3] Pei, S. C., & Chen, C. Y worked on the problem of color distortion, low contrast and loss of the human activity due to light scattering and absorption. Author proposed a revised underwater dehazing model aiming to eliminate the color of water directly while solving the problem of haze in the underwater images. Also a color correction method is proposed that can adaptively address the problem of color shifting without any additional information.The proposed algorithm consists of three primary stages: underwater dehazing, color correction and image detail enhancement. With a quantitative improvement of 5%–77% on each of the four evaluation performance metrics, experimental data show that the suggested method performs much better than competing methods. The proposed method can be applied to underwater detection and exploration as the pre-processing step.[4] Liu, P., Wang, G., Qi, H., Zhang, C., Zheng, H., & Yu, Z worked on the problem with scattering of light by suspended particles in water, raw underwater images which have low contrast, blurred details and color distortion. This paper proposes an underwater image enhancement solution through a deep residual framework. A cycle-consistent adversarial network (CycleGAN) is employed to generate synthetic underwater images as training data for convolution neural network models. Underwater Resnet model is proposed, which is a residual learning model for underwater image enhancement tasks. The proposed UResnet-P-A model achieved the best performance with regard to both color correction and detail enhancement than the other methods. UResnet-P-A model performs the best with 5.2196 UIQM score on testing data from the original UIQM score 3.1339.[5] Wang, Y., Song, W., Fortino, G., Qi, L. Z., Zhang, W., & Liotta, A explained the problem of quality degradation due to light absorption and scattering in water medium. Author studied image correction and restoration techniques that address common distortions and degradations of underwater images. Underwater restoration methods are reviewed considering both the IFM-free and the IFM-based approaches using both subjective and objective analysis. Average Entropy value for IFM-free underwater image enhancement 7.04 and for IFM-based under water restoration the average Entropy value is 6.77.Finally author provided an experimental-based comparison of the state-of-the-art quality improvement methods using multiple quality assessment metrics.[6] Anandh, R. V., & Devi, S. R mentioned that The visual quality of underwater images is degraded because of two main factors namely, backscattering and attenuation. This paper aims to propose a single image enhancement technique without the use of any external datasets. The degraded images are subjected to two main processes namely, color correction and image fusion. After color correction, the image is put through a fusion process in which it is divided into two copies and given a white balance and contrast boost. Contrast enhancement process applied to the two versions of the image obtained in the restoration process .RGB plot is estimated to distinguish the color difference obtained between the input and resultant image.[7] Han, Y., Huang, L., Hong, Z., Cao, S., Zhang, Y., & Wang, J proposes a deep supervised residual dense network (DS-RD-Net), used to better learn the mapping relationship between clear in-air images and synthetic underwater degraded images.DS-RD-Net first uses residual dense blocks to extract features to enhance feature utilization then, it adds residual path blocks between the encoder and decoder to reduce the semantic differences. Compared with the other underwater image enhancement method, the proposed method fully retains the details of the content and structure of the original image .Experiments results (PSNR was 36.2, SSIM was 96.5%, and UCIQE was 0.53) demonstrated that the proposed method can fully retain the local details of the image while performing color restoration.[8] The latest methods for underwater image enhancement are based on deep models, which focus on finding a mapping function from the underwater image subspace to a ground-truth image subspace. In this paper, author proposed a Class-condition Attention Generative Adversarial Network (CA-GAN) to enhance an underwater image. In the channel attention block, the feature maps in the front-end layers and the back-end layers are fused along channels, and in the spatial attention block, feature maps are pixel-wise fused. At the same time, the results of proposed CA-GAN can display more realistic scene colors and fewer artifacts comparing to HLP18.[9] Zhou, Jingchun, Dehuan Zhang, and Weishi Zhang proposed a visual quality enhancement method for underwater images based on multi-feature prior fusion (MFPF), achieved by extracting and fusing multiple feature priors of underwater images. The algorithm realizes the color offset correction based on the dominant color of the underwater image. The data set of the experiment includes the RUIE data set , UIEBD data set , and Dalian Zhangzidao dataset (DLZZD). The experimental results show that by applying the multi-feature prior fusion scheme, this design comprehensively solves various degenerated problems, removes over-enhancement, and improves dark details.[10] Estrada, Dennis C., Fraser R. Dalgleish, Casey J. Den Ouden, Brian Ramos, Yanjun Li, and Bing Ouyang developed to capture images taken in degraded underwater environments and provides superior range and image contrast over conventional optical cameras .One advantage of using the MEMS scanner is that it can simultaneously switch between sparse and dense scans Image Enhancement Results are taken from PNNL Optical Test Facility dataset. Additionally, the UMSLI system is eye-safe and unobtrusive to marine life by incorporating an inexpensive low-power red-laser diode.[11] Tianci Li a,b , Jianli Wang a , Kainan Yao proposes that a novel picture dehazing technique is developed in this research that combines optics and

image processing technologies. Through the use of polarisation technology, a portion of the backscattering can be removed directly, and the dehazing of the image can then be promptly resolved using the suggested approach. The goal of image enhancement technology is to increase object contrast without taking into account the factors that contribute to image deterioration, therefore the author presented a novel dehazing strategy that combines optics and image processing technologies to address this issue. The underwater object is first actively illuminated with linear polarisation light, and then a linear polarizer is placed in front of the camera so that a significant portion of the backscattering light and a portion of the object light of the object with strong polarisation maintenance can be removed optically. The outcomes demonstrate that the algorithm can provide a high-quality dehazing effect for objects formed of various materials as well as for grey and colour images in a scattering environment of different concentrations.[12] A novel domain adaptation framework for transfer learning-inspired real-world underwater image improvement is proposed that applies in-air image dehazing to real-world underwater image enhancement. In order to transform underwater images to in-air images using a CycleGAN, we first train an image translation network using clear air-domain images and the original underwater images. The second goal of the picture enhancement module is to eliminate blur in order to enhance the quality of underwater images. After this module, the input underwater photos without water tones are converted into the final clear UIE outputs. The suggested method outperforms existing techniques on both synthetic and real-world underwater photos, including images with various colour casts, haze-like casts, and objects.[13] Shidong Zhu, Weilin Luo and ShunqiangDuan explains that this study intends to improve underwater photographs in all respects, including colour, clarity, and contrast. An underwater generative adversarial network and a CNN-based all-in-one dehazing model, respectively, reduce colour deviation and blur to accomplish this. The contrast enhancement of underwater photos uses an adaptive contrast improvement that includes adjustable histogram equalisation and contrast constrained adaptive histogram equalisation. CNN's all-in-one model improves both the clarity and the colour harmony. The overall visual effect can be greatly enhanced in terms of colour harmony, clarity, contrast, and details by incorporating contrast improvement. Since the suggested approach addresses the issues of underwater image colour degradation, image blur, and low contrast, it may effectively improve the quality of underwater images. [14] Mi, Z., Li, Y., Wang, Y., & Fu, X proposed a multi purpose oriented method is implemented by manipulating information. This improves visibility of images and decrease the noise in the images. Firstly the image is decomposed into both illumination and reflectance layer and then the brightness is increased by tradition methods i.e, color correction and contrast enhancement. The three steps are illumination and reflectance estimation , multi-scale decomposition and post-processing of image data. The results of images increase brightness, contrast and color and the proposed method improves accuracy, robustness and performance in diverse water images and lightening types. The metrics where the performance is compared are PSNR,PCQI,UIQM and UCIQE.[15] In this study a revised underwater dehazing model is developed to eliminate the color of water directly while solving the problem of haze in the underwater images. MSR-PO algorithm is used that measures by (NR- IQA) for assessment. By these indexes the parameters are designed where the performance is evaluated. The evaluator NIQE is the evaluation index of NR-IQA. The GSA algorithm i.e., Gravitational search algorithm is used in this model for enhancing the images by multi-scale Retinex based method and NIQE index . This algorithm improves the speed of the process and reduces time complexity. The metrics that are used to measure the performance of the proposed model are entropy, UCIQE, NIQE, UIQM .The algorithm used results good adaptive ability and performs better in both qualitative and quantitative approaches by using new optimized metrics of evaluation.[16] In this study a novel joint iterative network model, dehazing module and iterative mechanism will help in image enhancement .The first process which is done in the study is color correction process that results images of similar distribution of color channels . This is called as triple color balance method. The next module used is Recurrent Dehazing Module(RDM) where multiple iteration are made for getting dehazing features. Finally, a Joint iterative refined module is built by integrating the two components that updates features in all the iterations. The method in the work results the best results than traditional methods and the disadvantage is that synthesizing the dataset is necessary where real images don't match synthesize images. The performance metrics are PSNR and SSIM. The future work is to synthesize the dataset and work on feasibility in other applications.[17] To solve degradation issues, an underwater image enhancement network via medium transmission-guided multi-color space embedding, called ucolor is proposed. A visual quality enhancement method for underwater images based on multi-feature prior fusion (MFPF), achieved by extracting and fusing multiple feature priors of underwater images. This paper studies low-light image enhancement algorithms, aiming to improve the quality of low-light images by studying some technical means and methods. Techniques is rapidly increasing the ability to image objects in the sea. The underwater image suffers from low contrast and resolution due to poor visibility conditions Poor visibility in water.[18] Underwater images suffer from color casts and low contrast due to wavelength- and distance-dependent and scattering. Underwater image enhancement is a field of image processing that aims to improve the visual quality of images taken underwater. His can be particularly challenging due to the unique properties of light in water, which can cause colors to appear distorted and images to appear blurry. One technique that has been developed for underwater image enhancement is called medium transmission-guided multi-colour space embedding. [19] Enhancements are used to make it easier for visual interpretation and understanding of imagery. The advantage of digital imagery is that it allows us to manipulate the digital pixel values in an image. Enhancement of underwater images is essential for inspection of underwater infrastructure and detection of many man-made objects. An image transform can be applied to an image to convert it from one domain to another.[20] Underwater image enhancement via multi-feature prior fusion is a technique that involves combining multiple different types of information, or "features," about the image in order to improve its visual quality. This can include information about the colors in the image, the edges and details in the image, and other characteristics of the image. To perform this enhancement, the technique uses a machine learning model that has been trained on a dataset of images with known characteristics. The model is then used to identify and enhance the important features in the input image, resulting in an improved image.[21] Han, R., Guan, Y., Yu, Z., Liu, P., & Zheng, H proposed an effective method using Spiral GAN where the model includes convolution and deconvolution blocks are included with a spiral strategy that results in clear images with different colors and goo contrast. This spiral strategy and pixel level loss function will enhance the images into quality images with rich details and different colors. The datasets used in URPC,EUVP,UNDERWATER-MOT and RUIE where the proposed model is tested by these datasets with the performance. The performance metrics are UISM , UICM ,UIConM , UIQM. The major advantage is that the proposed method is effective and transforms images into qualitative and clean images. The future work is to work for improving translation quality for low-level images.[21] The new image registration and image fusion algorithm is developed utilizing the PCA method and by taking into account images from two different underwater datasets to identify the matched points. Image registration is a technique for combining diverse sets of data into a single coordinate system. The data may be gathered from various sources, including numerous pictures and various sensors. The two input images, image 1 (Source image) and image 2 (Image of a different view), are changed to grayscale images, which are referred to as Reference Image (IR) and Sensed Image (IS). and performed image registration on the sensed image (IS) by applying geometric transformations like 45-degree rotation. To determine performance metrics for the registered image, the Principal Component Analysis (PCA) approach is used after registration. To determine the accuracy and quality of photographs, this calculation is done. The correctness and quality of underwater images are checked using PCA for registered and fused images, and performance metrics like E, RMSE, PSNR, and ERGAS are calculated, achieving 98% accuracy.[22] In this study, the image enhancement is done by global and local equalization with fusion process at the end to get qualitative images. The four stages in developing the model are pixel intensity center regionalization, global equalization of histogram, local equalization of histogram and multi-scale fusion .The major algorithms used are GEH,LEH and DIMCF. The performance metrics are AG,PCQI, UCIQE. The major advantage is that this method produces effective results than traditional methods in qualitative and quantitative analysis. The disadvantage is that the enhanced images cannot achieve the consistency of the background color captured by cameras and images taken at different levels of turbidity. The future work of this is to work on gaining the consistency of images.[23]Yang, M., Hu, K., Du, Y., Wei, Z., Sheng, Z., & Hu, J explained a conditional GAN architecture is used for image enhancement by multi scale generator and dual discriminator. The multi-scale generator is used extraction and the dual discriminator improves the quality of the images and the loss function is used in optimization of the process. The main advantage is that the proposed method results better performance and realistic results than state-of-the-art-methods. The performance metrics are PSNR,SSIM.. The main disadvantages of the proposed model are the method only focus on removing the color and improving the contrast and gap between results and real images is not clear due to the limited testing. The future work of the is to focus on the limitations to upgrade the quality of images where the clarity is improved and focusing is also to be on the whole image features.[24] Li, C., Tang, S., Kwan, H. K., Yan, J., & Zhou, T presented a novel color correction method based on color filter array (CFA) and an enhancement method based on Retinex with dense pixels and adaptive linear histogram transformation for degraded color- biased underwater images. Retinex model has been widely used to efficiently handle low brightness and blurred images. Author designed a scheme to gain much well-distributed and denser pixels to obtain more precise intensity of illumination also a piecewise linear function for histogram transform, which is adaptive to the whole RGB value. Proposed algorithm achieved Entropy value of 7.73 and the enhancement method can greatly improve underwater images visual effect and has excellent performance indices. The images processed by proposed method have clearer details, uniform visual effect, and better color-correction results comparing with state-of-the-art methods.[25] worked on color distortion and low contrast, which dramatically affects the target detection and measurement tasks in the underwater context. Author used a multistage generative adversarial network for better visual perception of underwater images using extensive multi-scale context feature learning and high-precision restoration .Author introduced a Gaussian noise into the generator which enriches the details of images and the relative discriminator, which promotes the generated image to have more realistic edges and textures. Experimental results demonstrate the superiority of proposed method over state-of-the-art methods in terms of both quantitative metrics and visual quality. The proposed method obtained Structural Similarity Index value of 84% compared to existing algorithms.[26] Lin, J. C., Hsu, C. B., Lee, J. C., Chen, C. H., & Tu, T. M worked on underwater images with blurriness, lack of contrast, and low saturation due to the physics of light propagation, absorption, and scattering in seawater. Author proposed a generative adversarial network (GAN)-based solution and generate high-quality underwater images equivalent to given raw underwater images. With two different datasets, author compared the proposed model with other enhancement methods and conducted several comparisons and demonstrates via full-reference and non- reference metrics. SSIM value of proposed method D-GAN achieved 89.4% compared to existing methods for Image Restoration DGAN with dilated concatenation removes this block effect at the cost of decreased UIQM performance.[27] Liu, S., Fan, H., Lin, S., Wang, Q., Ding, N., & Tang, Y worked on images that suffer from color casts and low illumination due to the scattering and absorption of light as it propagates in water. Author proposed an adaptive learning attention network for underwater image enhancement based on supervised learning named LA-Net to solve these degradation issues. Also designed a novel parallel attention module (PAM) to focus on the illuminated features and more significant color information coupled with the pixel and channel attention. Then, an adaptive learning module (ALM) can retain the shallow information and adaptively learn important feature information. SSIM value of proposed method LA-Net achieved 90.85% compared to existing methods and shown excellent performance different images underwater datasets.[28] Liu, R., Jiang, Z., Yang, S., & Fan, X worked on the problem in underwater images which suffer from severe distortion, which degrades the accuracy of object detection in underwater environment. Author proposed an object-guided twin adversarial contrastive learning based underwater enhancement method to achieve both visual-friendly and task-orientated enhancement. The contrastive principle is also introduced into the training process to enforce the results with more realistic appearance. They provided the enhancement module with a task- aware feedback module to propagate the object guidance in order to provide more detection-favorable aspects to the enhanced outcomes. Proposed method achieved 87% of ‘mIoU’ than existing T-GAN-CP method with 79% and also superior to other top-performing methods in terms of quality improvement and detection accuracy.[29] In this study, after the CCT preprocessing filtering and fusion processes are done for improving the effectiveness . The methods used are MSRCR and color correction. After the dehazing method a fusion process that is a smoothening filter method is used for the color correction process and improving quality by holding details. The performance metrics are SNR,UIQM and entropy. The major advantage by this method is that the process results in better effectiveness in dehazing of image and the disadvantage is that the realization effect is not ideal in this method. In the future work of extension there could be a work on short comings.[30] An enhancement technique is developed by finding the relations or feature matching. This uses Siamese encoder and Correlation feature fusion module and compared results with three datasets. The method used UICoE-Net. The approaches used are Cooperative enhanced strategy and underwater image Co- enhancement network that contains Siamese encoder , correlation feature matching module and Siamese decoder. The method is run by using two datasets i.e., UIEB, UICoD and SQUID. The performance metrics used are SSIM,PSNR and MSE where these are measured by various methods along with the proposed method such as CLAHE ,fusion , Retinex , U-Net , Water-Net etc.The major advantage is that effectiveness is increased by the network used. The future work of this is to work on efficient correlation calculating strategies and performing video enhancement.

## 3.METHODOLOGY




## 4.CONCLUSION:

Underwater image enhancement is very much necessary to analyze the details of the image in depth and the latest methods have potential to increase the quality of images. The histogram equalization as a preprocessing technique and a GAN model for underwater image enhancement on the EUVP dataset yields outstanding results. The approach successfully restores the underwater images by enhancing their visual quality and making them more appealing to the human eye. The GAN model creates realistic and natural-looking images by learning the dataset's underlying distribution, while the histogram equalization technique was crucial in boosting the contrast of the images. The quality is assessed by different metrics such as PSNR.UIQM and MSE values. Therefore, it can be said that the method is a very good way to improve the quality of underwater images, which is good for many underwater applications like oceanography, marine biology, and underwater surveillance.

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